Model independent Breit-Wigner parameters of nucleon resonances $S_{11}(1535)$, $S_{11}(1650)$ and $P_{11}(1710)$

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Estimates of Breit-Wigner parameters of nucleon resonances were obtained by phenomenological analysis of η-meson photoproduction on protons performed completely by statistical procedures without appealing to theoretical models.

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We have used the results of our energy independent analysis of angular distributions of the process $\gamma p \to \eta p$ [1]–[3]. The analysis was based on expansion the differential cross sections $d\sigma(\theta)/d\Omega$ measured at definite CM energy W in series in Legendre polynomials $P_i(\cos\theta)$:

$$\frac{k}{q}\frac{d\sigma(\theta)}{d\Omega} = \sum a_i P_i(\cos\theta)\,,$$

where k and q are CM momenta of gamma quantum and η-meson respectively. The use of such nonparametric statistical model provides unbiased estimates of the coefficients a_i where a_0 is the sum of squares of the multipole amplitudes of photoproduction process. The values a_0 as function of CM energy W and its multipole decomposition were given in [1]–[3]. In present analysis we use mainly the experimental results of GRAAL collaboration obtained in energy region W from 1490 to 1724 MeV [4]. This energy region contains the following nucleon resonsnces with the same quantum numbers of spin and isospin: $S_{11}(1535)$, $S_{11}(1650)$ and $P_{11}(1710)$.

The main task of the analysis is to describe the energy dependence of $a_0(W)$ using statistical models based on Breit-Wigner formulae similar to [5]. The fitted parameters of resonances were mass W_R, full width Γ_R and helysity amplitude $A_{1/2}$.

To keep the possibility of testing the statistical hypotheses we devided the whole energy region by intervals in accordence with measured in [4]. In every interval the statistical quality of description of resonances by parametric Breit-Wigner models with one, two and three resonances: $S_{11}(1535)$, $S_{11}1535) + S_{11}(1650)$ and $S_{11}1535) + S_{11}(1650) + P_{11}(1710)$ was tested. The results of this test based on criterion χ^2/ν are presented in table 1.

Table 2 contains the estimates of fitted parameters of nucleon resonances selected accordingly table 1 as the most reliable. Table 1 and 2 contain also the results obtained with inclusion additional experimental data of GRAAL [6]. In all cases the fitted values are within the limits of statistical uncertances. Systematic errors in all cases were not taken into account. It should be noted that all procedures used are completely statistical, providing model independent estimates of Breit-Wigner parameters of three nucleon resonsnces $S_{11}(1535)$, $S_{11}(1650)$ and $P_{11}(1710)$. At the same time the values of Breit-Wigner parameters of nucleon resonances obtained by means of various theoretical models with some free parameters, for example, various versions of isobar model [5, 7], dispersion relation [8], quark models [9] etc are not only model dependent but lead to contradictory results (for instance [8]).

[1]deceased

Table 1: Values of criterion χ^2/ν, used in procedure of hypotheses testing

References	[4]						[4, 6]
Energy interval ΔW, MeV	1490 – 1584	1490 – 1603	1490 – 1622	1490 – 1659	1490 – 1676	1490 – 1716	1490 – 1724
Model with single resonance	1.48	1.29	19.4				
with two resonance				1.67	1.3	8.96	
with three resonance						1.36	3.97

Table 2: Values of Breit-Wigner parameters of nucleon resonances $S_{11}(1535)$ ($\beta_{\eta N} = 0.55$, $\beta_{\pi N} = 0.35$), $S_{11}(1650)$ ($\beta_{\eta N} = 0.08$, $\beta_{\pi N} = 0.77$) and $P_{11}(1710)$ ($\beta_{\eta N} = 0.06$, $\beta_{\pi N} = 0.15$). Here β_{iN} are fractions Γ_{iN}/Γ_R.

References		[4]			[4, 6]
ΔW, MeV		1490– 1603	1490 – 1676	1490 – 1716	1490 – 1724.
$S_{11}(1535)$	W_R, MeV	1538.62 ± 0.69	1538.06 ± 1.12	1538.64 ± 1.77	1539.47 ± 4.15
	Γ_R, MeV	163.0 ± 4.09	163.27 ± 6.45	169.16 ± 9.21	174.79 ± 19.49
	$A_{1/2}$, $\frac{10^{-3}}{\sqrt{\text{GeV}}}$	99.23 ± 1.01	101.44 ± 2.37	105.66 ± 5.44	112.02 ± 18.23
$S_{11}(1650)$	W_R, MeV		1636.58 ± 1.4	1640.31 ± 4.2	1642.74 ± 6.27
	Γ_R, MeV		78.24 ± 11.2	110.63 ± 30.81	145.06 ± 78.72
	$A_{1/2}$, $\frac{10^{-3}}{\sqrt{\text{GeV}}}$		36.2 ± 5.8	61.96 ± 28.99	99.47 ± 111.73
$P_{11}(1710)$	W_R, MeV			1708.75 ± 1.71	1712.88 ± 2.03
	Γ_R, MeV			45.47 ± 15.73	48.74 ± 18.8
	$A_{1/2}$, $\frac{10^{-3}}{\sqrt{\text{GeV}}}$			59.28 ± 19.03	72.3 ± 32.89
	χ^2/ν	1.29	1.3	1.36	3.97

We hope that model independent data on nucleon resonance parameters may prove to be useful in view of the problem of resonsnce nature [10].

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